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Context Reconsidered: Complex Signal Ensembles, Relational Meaning, and Population Thinking in Psychological Science

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This article considers the status and study of "context" in psychological science through the lens of research on emotional expressions. The article begins by updating three well-trod methodological debates on the role of context in emotional expressions to reconsider several fundamental assumptions lurking within the field's dominant methodological tradition: namely, that certain expressive movements have biologically prepared, inherent emotional meanings that issue from singular, universal processes which are independent of but interact with contextual influences. The second part of this article considers the scientific opportunities that await if we set aside this traditional understanding of "context" as a moderator of signals with inherent psychological meaning and instead consider the possibility that psychological events emerge in ecosystems of signal ensembles, such that the psychological meaning of any individual signal is entirely relational. Such a fundamental shift has radical implications not only for the science of emotion but for psychological science more generally. It offers opportunities to improve the validity and trustworthiness of psychological science beyond what can be achieved with improvements to methodological rigor alone.

Public Significance Statement
Psychological science is a set of ideas and practices conditioned on assumptions about what a mind is and how mental events are caused. These assumptions reverberate much further, influencing medicine, education, industry, and other aspects of public life. This article uses three well-trod methodological debates about emotional expressions as a lens to challenge a particular set of assumptions and consider an alternative that might improve the validity and robustness of psychological science.

Keywords: context, emotion, construction, variation, relational meaning

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Take a look at the woman in Figure 1, screaming in terror. Her eyebrows are furrowed, her eyes are pinched tight, and her mouth is agape. She could be in danger or witnessing a horrific scene. She is obviously terrified out of her wits.

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Figure 1
A Woman's Face (Photo Credit: Barton Silverman/The New York Times/Redux)

Except … she is not. This is actually a triumphant Serena Williams after she beat her sister, Venus, in the 2008 U.S. Open tennis finals (see Appendix, for the full photograph). When viewed in context, Ms. Williams's configuration of facial muscles instantly takes on a different emotional meaning.

I first published this example in 2011 to demonstrate the power of context to subtly transform the emotion you experience in another person's face (Barrett et al., 2011; for similar examples, see Aviezer et al., 2012; Barrett, Lindquist, & Gendron, 2007). Beneath this simple phenomenon lies a microcosm of century-long debates about the nature of emotions—the events we refer to with words like "anger," "sadness," "compassion," and "awe." The first half of this article carefully reviews and updates three well-trod methodological debates on the role of context in emotional expressions to unearth several problematic assumptions, or ontological commitments, about emotions as psychological events caused by isolated, universal processes that are independent of but moderated by context. The second half of the article weaves the existing evidence, plus ideas and evidence from other scientific disciplines, into an alternative approach with different ontological commitments: Psychological events emerge in ecosystems of signal ensembles, and the psychological meaning of any individual signal is determined by the other signals in the ensemble (i.e., meaning is entirely relational). To be clear, I am not suggesting that emotions and other psychological phenomena are illusions that do not exist in physical reality. They are indeed physically real, but real in a different sense than is traditionally understood (Barrett, 2012).

These entwined efforts—reconsidering ontological commitments about context that are hidden in our methods and crafting a different set of commitments within a multidisciplinary milieu—have been the focus of my work with mentees and collaborators for the past 30 years. Critiques of psychology's treatment of "context," particularly within laboratory experiments, have been raised now and then throughout the history of our field, giving rise to important lines of research. Yet, these efforts have somehow remained siloed, so that the dominant scientific paradigm in psychology continues to consider context as a mere moderator of universal processes that can be observed in lawful ways by manipulating one or two isolated variables. This traditional view of "context" remains resilient, in part, because prior critiques have rallied efforts to improve the methodological rigor of such experiments, rather than question their suitability for studying psychological phenomena in the first place. Considerable scientific opportunities still await, it turns out, particularly for improving the validity and trustworthiness of psychological science, if we take more seriously the idea of a fully relational science of psychology and reconsider our shared empirical practices accordingly. The discussion in the second half of the article is more aspirational than prescriptive, a sort of conceptual "call to arms" by design. It sketches an emerging scientific landscape that offers exciting opportunities for scientific discovery, particularly for the next generation of psychological scientists with intrepid spirits and open minds.[1]

The Importance of Context

A single configuration of facial muscles in motion, such as a smile or a scowl, can take on different emotional meanings depending on the context. This observation is not controversial. The power of context to shape one person's experience of another person's face has been consistently noted for thousands of years (see online Supplemental Materials, Box 1). In the early 20th century, formal psychological demonstrations of context effects began appearing in scientific talks and journals (e.g., Sherman, 1927) and have continued ever since (for reviews, see these articles and references therein: Barrett et al., 2019, online Supplemental Materials Box 3; Gendron & Barrett, 2017; Gendron et al., 2013). A common interpretation of such findings is that context situationally tunes biologically prepared responses. Certain configurations of facial muscle movements are assumed to have inherent emotional meaning—they are presumed to display a person's internal emotional state with high specificity and consistency across situations, people, and cultural contexts. Scowls are thought to display anger, frowns are thought to display sadness, raised eyebrows with a slight smile are thought to display interest, and so on. I will refer to these ideas as a *typological view of emotion* because they assume that emotions such as fear, awe, anger, and disgust are a taxonomy of biologically prepared states, each with its own pattern of diagnostic signals (e.g., Cowen & Keltner, 2021) that can be adjusted by independent contextual influences. In this view, all

[1] Some topics covered in this article are associated with large, published literatures, which necessarily means that comprehensive referencing was not possible. To address this issue, I often refer to published articles authored or coauthored by members of the Interdisciplinary Affective Science Laboratory that contain relevant and important references from other labs, referring the reader to those other, equally important references with a suggestion to see "references therein."

things being equal, a person's facial movements are assumed to be a pretty good guide to the person's emotional state. A typological view of emotion, therefore, does not deny the influence of contextual factors. But contextual influence is assumed to be independent of the processes that cause emotions (e.g., Elfenbein, 2013; Levenson, 2011; Matsumoto, 1990; Roseman, 2001; Tracy & Randles, 2011). Therefore, contextual factors are thought to merely tweak, modify, or moderate inherent emotional meanings.

To better understand the role of context in a typological view, consider that each type of emotion is, in actuality, a category of many individual instances. Each instance (e.g., each instance of anger) can be described as a collection of features. Some features are physical, such as expressive facial movements and autonomic nervous system changes; and some are mental, such as affective feelings (e.g., pleasure/displeasure, level of arousal, effort), goals (e.g., to protect against threat, to affiliate), and appraisals, which describe how a person experiences their situation (e.g., novelty, goal congruence). In principle, any reference to "an emotion" is inherently ambiguous because it is unclear whether the referent is an individual instance or the entire category. In practice, a typological view reduces this ambiguity by assuming that each type of emotion, as a category, has a prototype, that is, an instance with a pattern of features that best describes all the category's instances. Individual instances of the category might vary in their features across situations, people, and cultures, creating a distribution (or family) of physical signals, but the prototype, as a conceptual representation of the entire distribution, is assumed to share a family resemblance with them. A category's prototype might be its most frequently observed instance (i.e., a typical instance) or its most representative instance. The prototype's features are assumed to be similar enough to the other category instances in the distribution, and different enough from the prototypes of other categories, to diagnose a new instance reliably and specifically as belonging to its specific emotion category. Indeed, in a typological view of emotion, an emotion prototype is considered to be a reliable suite of coordinated features (e.g., in peripheral physiology, motivation, and behavior) that serves as an evolved adaptation to a specific fitness-relevant challenge (Shariff & Tracy, 2011). Prototype categories have fuzzy boundaries, meaning their instances occasionally share some features with instances of other categories, and this is where context comes in. A wrinkled nose and scrunched up eyes, for example, are assumed by themselves to be an evolutionarily preserved, prototypical expression of disgust (Shariff & Tracy, 2011), but this configuration might express anger when it occurs attached to a body with balled fists (see Aviezer et al., 2008).

Evidence for a typological view of emotional expression can be found in hundreds of published studies that tried to remove as many contextual influences as possible, in the best tradition of rigorous experimental design within psychological science. The assessment of these designs as "rigorous" rests on the assumption that isolating a face from other contextual influences allows a precise causal inference between one person's facial movements and another person's experience of emotional meanings in those movements (i.e., the behavior of interest). These studies, referred to as "emotion recognition" studies, almost exclusively employed photographs of posed, disembodied faces that are considered devoid of context. Participants were asked to choose from an array of options which emotion they perceived in the posed facial configurations. At greater levels than chance, participants around the world saw anger in scowling configurations, sadness in frowning configurations, fear in wide-eyed gasping configurations, and so on. Controlling for context supposedly allows the inference that any emotional meanings in the facial movements experienced by participants must, logically, emanate from the faces alone. And if emotional expressions are universally recognized, the argument goes, then they must also be universally produced; and if they are universally produced, the argument continues, then they must be innate (Shariff & Tracy, 2011).

But were these faces, disembodied though they were, actually presented to participants without any context? Classic critiques have pointed out that similar experimental designs are composed of complex arrays of influences beyond those variables that are the intended focus of the experiment (e.g., Cronbach, 1975; Gergen, 1978; McGuire, 1973). In line with these criticisms, a number of scientists (including my collaborators, mentees, and me) suggested that these recognition experiments actually include potent contextual features, lurking unnoticed by the experimenters and participants, with sufficient power to mold the emotional meaning of the faces. If so, then these contextual factors travel along with the experimental methods from culture to culture, like stowaways, encouraging participants around the world to "recognize" certain emotional meanings. The methods obscure the complex nature of causality, allowing participants responses to be misinterpreted as evidence for universal emotional expressions. The implication is not that these studies are flawed. They discovered something important—just not what their designers think they discovered: context may not function just as a moderator of biologically prepared meanings but may serve as a full-fledged cause of those meanings.

Several forms of context have been the focus of persistent debate over the past century, creating a hornet's nest of methodological controversies. Let's carefully reexamine three sources of context that have been widely considered in the literature, extending the discussion with new findings about hidden contextual elements. We'll tackle contextual elements within choice-from-array methods, in repeated and blocked trials (allowing for cross-trial learning), and in the stimulus arrays selected for study. The goal in these discussions is to not suggest the need for more experimental rigor in these designs (in the traditional sense of psychology's so-called replication crisis or similar crises of the past) but to question psychology's use of a reductionistic experimental tradition in the first place. What hopefully becomes clear is that mere disagreements about methods (i.e., epistemological controversies) reveal deeper ontological disputes about the nature of emotion, the nature of psychological meaning, and how psychological phenomena are caused. That is, our goal is nothing less than to reconsider the causal influences that create a human mind and how to best study them with a scientific method.

Methods Issue 1: Context Embedded Within Choice-From-Array

A choice-from-array method presents participants with a stimulus (e.g., a face, a set of eyes, a vocalization, a scenario, a word) and asks them to select the corresponding target from a small array of choices (e.g., a set of words, faces, vocalizations, etc.). In studies of emotion recognition, this method comes in several flavors, all of which strongly constrain the emotional meanings that participants could experience in the facial movements of another person. In one common design, a participant views a photo of a face that is posing a configuration of facial movements (e.g., a scowl) and then must choose a word to describe the face's emotional meaning from a small set of options, such as "anger," "disgust," "fear," "happiness," "sadness," and "surprise." This means the participant cannot opt for "confusion," "groaning at a bad pun," or "gastric discomfort." Other versions of choice-from-array have similar constraints, such as when a participant is presented with a scenario or an emotion word and must choose a matching facial configuration from two or three options.[2] Research has shown that these contextual constraints harmonize participants' responses and increase the consistency of their answers within a study as well as across studies, particularly when testing people from non-Western cultures (for reviews, see Barrett et al., 2019; Gendron et al., 2018; Russell, 1994). This harmonization may be, in fact, one reason that choice-from-array was chosen as the preferred method for studies of emotion recognition (Ekman & Friesen, 1971, p. 125).

Of the hundreds of studies that seemingly provide evidence for universal emotion recognition (and are interpreted as evidence for universal emotional expressions), the vast majority employ choice-from-array methods. For example, in the most recent major meta-analysis of emotion recognition research, 95% of the included studies used choice-from-array and observed that participants from Western parts of the world (e.g., Germany, France, Italy, etc.) chose the expected word or face about 85% of the time on average; the results were slightly lower (72%) in cultures that are less similar to the United States (e.g., Japan, Malaysia, Ethiopia; Elfenbein & Ambady, 2002). These observed consistencies were the result of the faces' being viewed in context, rather than by the emotional meanings of the facial configurations alone, because choice-from-array shapes how participants experience the faces.

Research suggests that the emotion words employed in experimental trials are potent enough to actively shape the emotional meaning that the participants experience in another person's facial movements (e.g., Doyle & Lindquist, 2018; Lindquist, 2017; Lindquist et al., 2015; Gendron et al., 2012; Lindquist & Gendron, 2013; Satpute & Lindquist, 2021). When the contextual features embedded in choice-from-array are removed, giving participants more freedom in their responses, an explosion of variation is observed, in participants from the United States and other large, urban cultural settings (Barrett et al., 2019; Kollareth et al., 2021; Russell, 1994; Russell et al., 2003; and references therein) and in people from small-scale cultures from around the world. Since 2008, 11 published articles studying participants from small-scale cultures and using a variety of less-constraining methods have documented considerable variation in the psychological meanings experienced in faces posing hypothesized prototypic expressions (Gendron et al., 2018; Gendron, Hoemann, et al., 2020; and references therein).

Some amount of variation is consistent with a typological view, as noted earlier, because types of emotion are thought to be expressed by a family of related physical signals, each type having its own prototype. Some natural variation is therefore expected in the configurations that will be recognized as expressions of that type (e.g., Ekman, 1992). In other words, an expression of anger can look somewhat different on different occasions and still remain an expression of the underlying type for the proposed families of related signals (e.g., see Table 1 in Barrett et al., 2019). So, what's the big deal?

Well, the amount of variation is *vast*. For example, on viewing a scowling configuration, participants might infer that the poser is expressing sadness, concentration, hunger, or a desire to avoid a social interaction. When participants are offered the opportunity to apply nonemotional labels to facial configurations, they routinely choose to do so, sometimes at higher rates than the emotional options (e.g., Crivelli & Fridlund, 2018; Crivelli, Jarillo, et al., 2016; Crivelli, Russell, et al., 2016; Rychlowska et al., 2015). So, the issue boils down to magnitude. How many psychological meanings can a single facial configuration support and still be interpreted as evidence for a typological hypothesis? Likewise, how many different configurations can be experienced as expressing a single category of emotion and still be considered evidence for an expressive prototype with inherent biological meaning? How far can a typological view be stretched before it breaks?

[2] The choice-from-array procedure in which a participant hears a brief scenario (e.g., "You have been insulted and you are very angry about it") and must choose the corresponding "facial expression" from two or three photographs of posed facial configurations is called the Dashiell method, after its inventor (Dashiell, 1927).

Methods Issue 2: Context Hidden Within Repeated Trials

The context effect in choice-from-array studies, even if we accept it in general terms, cannot explain another source of evidence that supports the typological view: Some participants from small-scale, remote cultures match emotion words (with or without scenarios) and posed facial configurations (or vocalizations) at above chance levels when choosing from a small array of options (Ekman et al., 1969; Ekman & Friesen, 1971; Sauter et al., 2010; Tracy & Robins, 2008). Restricting participants' choices would harmonize their responses only if participants were already familiar with the facial configurations and their emotional meanings in the first place; without such familiarity, participants would have responded randomly. Such familiarity could only be learned, the logic goes, by persistent contact with U.S. cultural practices and norms, which these participants presumably had little of, hence their responses are evidence of universality. But recent research suggests that certain contextual features in classic choice-from-array designs have the power to subtly teach participants the answers that the experimenters expected, creating observations that have been interpreted as evidence for universal emotion recognition (and by implication, biologically prepared prototypes of emotional expression).

Humans are powerful statistical learners who can absorb complex, dynamically changing patterns of information in a short time, particularly when words are available to help. Words are invitations to learn categories (Waxman & Gelman, 2010), even for very young infants (Vouloumanos & Waxman, 2014). Such "supervised category learning" may, in fact, be an important source of emotional development (Hoemann, Wu, LoBue, et al., 2020; Hoemann, Xu, & Barrett, 2019) and more generally may support the transmission of cultural knowledge across generations, called cultural inheritance (Gelman & Roberts, 2017; Gendron, Mesquita, & Barrett, 2020). For example, young children quickly learn the emotional meaning of facial movements that they have probably never encountered before; children learned new categorizations for facial movements, based on associations with contextual features (including words), after only 12 min of experience (Woodard et al., 2022; also see Plate et al., 2019, 2022; Woodard et al., 2021). Relatedly, U.S. children performing a choice-from-array task learned to label an artificially constructed facial expression (e.g., a blowfish configuration) with the word "pax" at levels comparable to those for the expressive configurations that are thought to be universal (Nelson & Russell, 2016). Statistical learning may also contribute to a process-of-elimination strategy: Since the same words and photos are recycled across trials, words that are not chosen on prior trials are selected more frequently, inflating agreement levels (DiGirolamo & Russell, 2017).

A closer look at the aforementioned studies of small-scale cultures (e.g., Sauter et al., 2010, 2015) reveals other contextual elements that enhanced participants' ability to learn novel emotion categories across trials (as discussed in Gendron et al., 2015; Hoemann, Crittenden, et al., 2019). Experimental trials were blocked by emotion category, not randomized, which encouraged pattern learning and other strategies for completing the experiment in ways expected by experimenters. At the beginning of each block, participants completed an elaborate manipulation check that had the potential to teach novel emotion concepts (e.g., they listened to a brief emotional scenario, sometimes multiple times, and were required to explain their emotional understanding of the scenario; they were allowed to proceed to the experimental trials containing that scenario only when they explained the scenario "correctly," i.e., as expected by the Western experimenters). During each trial of a block, participants were presented with a scenario, a foil that varied from trial to trial, and a target stimulus that did not vary much, providing an opportunity to learn the intended emotional meaning of those stimuli, even if participants did not know those meanings at the outset (Gendron et al., 2015).

This "cross-trial learning effect" was confirmed in a study with participants from the United States and China, as well as Hadza (hunter-gatherer) participants, all of whom learned to match completely invented expressive signals (in this case, vocalizations) to nonuniversal emotion categories from around the globe (Hoemann, Crittenden, et al., 2019). Participants in all three samples, who did not have a preexisting category or word for any of the emotion categories being studied, nonetheless selected the contrived, target vocalizations at levels significantly above chance—at levels similar to those of prior studies in small-scale, remote cultures (as reported in Sauter et al., 2010)—strongly suggesting that the task constraints guided participants to respond in ways that made it appear as if the (contrived) expressions for nonuniversal emotion categories were universally recognized. Further evidence for the importance of cross-trial learning can be found in people who cannot learn new emotion concepts nor reassemble prior emotion knowledge, as needed, to complete the experimental tasks (Calabria et al., 2009; Lindquist et al., 2014; Roberson et al., 1999), in people who are experimentally prevented from reassembling that knowledge (e.g., Gendron et al., 2012; Lindquist et al., 2006; Roberson & Davidoff, 2000), and in young infants who do not have that knowledge to begin with (e.g., Caron et al., 1985; see online Supplemental Material Box 2). Findings like these suggest an alternative to typological views of emotion: People might not be detecting emotional meanings that are biologically embedded in facial movements; they might be constructing those meanings in relation to contextual factors.

Methods Issue 3: Context Hidden in the Sampling of Facial Configurations

The third contextual influence that we will consider is experimenter belief and its impact on constraining the stimuli used in emotion recognition experiments. Most studies of emotion recognition show participants a single facial configuration, posed by several actors, to represent the hypothesized prototypic expression for each emotion category. The exact configuration tested varies slightly from study to study (see Table 1 in Barrett et al., 2019; see Supplementary Table 1 in Le Mau et al., 2021), and by design each pose is usually exaggerated (Ekman et al., 1972); that is, the poses are caricatures of everyday movements (Goldstone et al., 2003). But these hypothesized prototypic expressions were not discovered by observing people as they express emotions in situ—they were chosen by scientists who were inspired by Darwin (1872/1965), who, by proclamation rather than observation, stipulated various configurations of facial muscle movements as expressions of emotions. Darwin's stipulations were based on drawings by Bell (1806) and photographs by Duchenne (1862/1990).[3]

An obvious avenue for improvement in evaluating any typological view of emotion would be to use a variety of facial configurations culled from everyday life, rather than a single, posed configuration for each emotion type, and examine the emotional meanings that participants experience in those faces. A recently published series of studies has done just that (summarized in Cowen & Keltner, 2021). Each study sampled thousands (and in certain cases, millions) of stimuli that were more naturalistic than the posed, disembodied caricatures of prior studies. Participants rated the emotional meanings they experienced in thousands of physical signals: in faces within the context of video clips (Cowen et al., 2021), in photographed faces that included body postures and surrounding context (Cowen & Keltner, 2020), in posed nonverbal vocalizations (e.g., laughs, screams; Cowen, Elfenbein, et al., 2019), and in thousands of speech samples that varied in prosody, spoken by actors from five countries (e.g., rhythm, timbre; Cowen, Laukka, et al., 2019). The studies also included a few other design elements in an attempt to avoid limitations of previous studies. They used sophisticated machine learning (ML) methods. They used both choice-from-array (involving 31 emotion words) and a relaxed choice-from-array so large that it functioned like a less-constrained free-response format, compared the two, and found no statistical difference in participants' responses.[4] One study also found that situational context had a minimal influence on the emotional meanings that participants experienced in face-plus-body stimuli (Cowen, Elfenbein, et al., 2019). All studies in this series appear to support the hypothesis of emotion prototypes (although the number of types varies from study to study). In the authors' words, "Upwards of 25 distinct varieties of emotional experience have distinct profiles of associated antecedents and expressions" (Cowen & Keltner, 2021, p. 124), and "pure expressions of fear, surprise, and awe are bridged by gradients of composite facial–bodily and vocal displays that reliably transmit intermediate meanings. Although there may be modal emotion-related responses, much of human emotional life is more complex" (Cowen & Keltner, 2021, p. 128; numbers referring to references cited within this article were removed from this quote). Similar observations were reported in a recent study of college students in China, India, Japan, Korea, and the United States who listened to 22 brief scenarios, each describing an event that might cause one of 22 emotions (e.g., "You have been insulted, and you are very angry about it") and were instructed to pose the facial expression they believed they would make if the events in the scenario were happening to them (Cordaro et al., 2018). Such findings, when viewed through a typological lens, appear to provide convincing evidence that people express distinct types of emotion with prototypic physical signals and recognize the biologically prepared expressive meaning of those signals, in a way that is independent of, but moderated by, situational context.

How do we square these newer findings with the larger landscape of studies (some of which we discussed earlier) in which participants experienced many psychological meanings in smiles, frowns, scowls, and other facial configurations—much more variation, in fact, than can comfortably be accounted for by a prototype structure? One possibility is that these new ML studies simply disconfirm all those other studies and finally put this debate to rest.

Another possibility is that these ML studies, by virtue of their design and modeling choices, continue the tradition of introducing experimenters' beliefs and stipulations as contextual constraints that are not present in real life, thereby restricting possible observations in subtle yet pernicious ways. We all know that ML algorithms do not prevent biases from creeping into stimuli, training data, and test data, and the same is true for these newer ML studies (e.g., see Barrett, 2021). For our purpose in this article, however, let's focus on just one vector for embedding experimenter beliefs: the stimuli sampled for these studies, that is, the range of physical signals that participants were exposed to.

In these newer ML studies, the face stimuli, though numerous and variable, were not randomly sampled; they were curated according to experimenters' beliefs about the nature of (English) emotion categories they chose to study.[5]

[3] For historical details, see Ekman et al. (1972), Gendron and Barrett (2017), Leys (2017, pp. 49–71), and Russell (1994). Other sets of universal expressive forms were proposed by various artists (see Barrett et al., 2019, online Supplemental Material Box 4).

[4] "[A]s participants typed, a drop-down menu appeared displaying items from a corpus of 600 emotion terms containing the currently typed substring. For example, typing the substring 'lov-' caused the following terms to be displayed: love, brotherly love, feeling loved, loving sympathy, maternal love, romantic love, and self-love" (Cowen & Keltner, 2020, p. 354).

[5] The internet, which is a curated version of reality, not a substitute for facial movements as they occur in the real world. The authors acknowledge this limitation. They wrote, "given potential selection bias and the scope of online images, we do not claim that the expressions studied here are exhaustive of facial-bodily signaling" (Cowen & Keltner, 2020, p. 353). But the authors seem less aware of the potential biasing impact of their own theoretical beliefs. For example, Cowen and Keltner (2020, p. 353) wrote, "The categories were derived from taxonomies of prominent theorists (see Keltner, Sauter, et al., 2019), along with studies of positive emotions such as amusement, awe, love, desire, elation, and sympathy (Campos et al., 2013); states found to occur in daily interactions, such as confusion, concentration, doubt, and interest (Benitez-Quiroz et al., 2016; Rozin & Cohen, 2003); and more nuanced states, such as distress, disappointment, and shame (Cordaro et al., 2016; Perkins et al., 2012) … These categories by no means represent a complete list of emotion categories, but instead those categories of expressive behavior that have been studied thus far."

There are thousands of anatomically viable facial configurations.[6] Given this plausible variation, what is the likelihood that a search for facial configurations, supervised by typological beliefs about emotion, will capture the breadth and variation of expression that exists in the real world (e.g., laughing in anger, sobbing in happiness, or falling asleep in fear)?[7]

To be fair, the ML articles in question explicitly state that stimuli were not chosen to maximize their "resemblance to category prototypes" (Cowen & Keltner, 2020, p. 353). Yet, various sources of bias creep into ML studies of emotional expression (see Domnich & Anbarjafari, 2021; Rhue, 2019), despite best intentions. Even stimuli used to induce instances of emotion are selected in line with typological beliefs (see Kragel, Reddan, et al., 2019; Wager et al., 2015). And experimental evidence shows that if an experimenter has a prototype in mind and curates stimuli guided by that belief, participants will be able to infer the prototype, even if they were never exposed to it (Posner & Keele, 1968). It is therefore plausible that stimuli used in the aforementioned ML studies failed to sample the full range of variation in the real world simply because the researchers who "selected expressions for apparent authenticity" (Cowen & Keltner, 2020, p. 353) believe strongly in the existence of biologically prepared emotion types.[8]

Luckily, we do not have to argue hypotheticals. Other published studies of emotional expression and emotion recognition demonstrate that small changes in how stimuli are curated have a big impact on the results, no matter how vast the data set or how sophisticated the ML, in part because such studies include stimuli that allow for the possibility of disconfirming a typological hypothesis. Consider a recent study, for example, in which researchers identified English nouns, verbs, adjectives, and adverbs that refer to emotion categories, along with their semantic and lexical relations (Srinivasan & Martinez, 2021). These words were translated into five other languages (Spanish, Mandarin Chinese, Farsi, Arabic, and Russian), and all six languages were used in a variety of internet search engines to identify and download over 7 million images of human faces. Each image was electronically coded for its facial muscle configuration using the Facial Action Coding System (FACS), and code accuracy was manually verified. Only 35 facial configurations, which appeared in only 1.87% of the 7 million culled images, were found in images derived from the search in all six languages, and none matched the configurations proposed by Darwin or were the hypothesized prototypic expressions (Another eight configurations were identified as common to images mined in one or more language, but not in all six.)[9] When participants freely labeled the 35 configurations for their emotional meaning, substantial variation was observed (more than mere accents on a universal prototypic expression and more than blends of presumed prototypic expressions). Once again, when participants were granted more freedom to experience a variety of meanings in any facial configuration, more variation was observed than a typological view can easily handle.

A different sampling strategy—one that was not supervised by specific emotion words or specific emotional situations—yielded even more situated variation in expressive configurations, while also providing yet more evidence of the causal power of context (Le Mau et al., 2021). We used photographs posed by 180 well-known, highly experienced actors to portray characters in over 600 realistic scenarios rich with psychological meaning (e.g., "[A woman confronts] her lover who has rejected her, and his wife, as they come out of a restaurant"); each scenario was posed only once (Schatz et al., 2013; Schatz &

[6] A human face can make a multitude of movement patterns: 16 million different combinations (or thereabouts) are possible, in principle, assuming each facial muscle can move independently (ignoring temporal dynamics). In addition, facial muscles can contract with different intensities and varying time to peak contraction (Jack & Schyns, 2017), further increasing the number of movement patterns that a face can generate (and the number of possibilities expands when another signal, such as body postures or vocalizations, is added to the mix). In practice, a much smaller subset of combinations is likely because of anatomical constraints (e.g., some muscles are more or less likely to move together because of their relative positions, how they are attached to facial bones, or how they are innervated by nerves).

[7] Falling asleep in fear has been documented in Bali (Bateson & Mead, 1942) and probably derives from a defensive slowing of the heart (bradycardia) in sea animals.

[8] The complete sentence is, "Given the large imbalances in the rates of expressions that appear online (e.g., posed smiles), we selected expressions for apparent authenticity and diversity of expression but not for resemblance to category prototypes." Here's another example with several sources of implicit bias. In Cowen et al. (2021), English speakers living in India were asked to find YouTube videos that likely contained emotional expressions. They then annotated the emotional meaning of the faces in 186,744 YouTube clips (1–3 s each), and they selected the emotion words (from a list of 29 emotion words plus the words "neutral," and "unsure") that they believed described the emotional meaning of the faces. These data were then used to train an ML algorithm to identify emotional expressions in over 6 million videos. The first source of bias was that one third of the labels were excluded from the final analysis because of low predictive accuracy, high correlation with a better predicted label, or because "uninteresting aspects of facial posture appeared to affect annotations (love annotations were affected by kissing and ecstasy by closed eyes)" (Cowen et al., 2021, p. 258). A second source was that bounding boxes were placed around the individual faces, leaving the rest of the scene unobstructed, meaning that raters were not labeling faces alone but faces in context. The third source of bias was a doozy. A deep neural network was trained on what one group of English-speaking Indian raters believed about the facial expressions of 16 emotion categories. The network then applied those beliefs to millions of videos from around the world to classify (i.e., identify) facial movements as expressions of those 16 emotion types. Neither the ratings that trained the network nor the resulting classifications could be validated against the actual state of the people in the videos (i.e., there was no way to know whether a scowl meant a person was angry, concentrating, or experiencing a bout of gas), yet they were accepted as ground truth. This is, in effect, an example of ethnocentrism embedded in code.

[9] Consider also that this search strategy likely underestimated the actual variation in the real world because many other languages (including those from nonindustrialized cultural contexts) were not included, and the other languages (including the five sampled in this study) contain emotion categories named with words that are not easily translatable into single English words and therefore were not sampled.

Ornstein, 2006). These photos are a goldmine for emotion research: Even though the facial configurations were not spontaneous, they were posed by award-winning, world-class actors whose professional reputations and livelihoods depend on conveying emotional meaning in realistic ways. Each evocative scenario was rated for emotional meaning using a choice-from-array method (by design, to tilt the odds in favor of a typological view), as was the corresponding facial pose, presented either alone or with its scenario for context, and the facial configurations were also coded using FACS.[10] Considerable variation was observed in the facial poses associated with scenarios of similar emotional meaning, replicating the Srinivasan and Martinez's (2021) study. An ML analysis of the facial configurations, supervised by emotional ratings of their corresponding scenarios, indicated that experienced actors posed a wide variety of context-sensitive facial configurations for each emotion category. The usual "prototypes" proposed in the literature were neither typical nor representative, although some were posed more often than expected by chance. These findings, which call into question the existence of stable, static prototypes, were statistically robust (as assessed with a multiverse analysis (Steegen et al., 2016) that examined the findings across a range of analytic choices, exhausting all potential combinations between them).[11]

A recently published meta-analysis of spontaneous facial expressions of emotion (Durán & Fernández-Dols, 2021) conceptually replicated the aforementioned studies that call a typological view of emotions into doubt. The proposed prototypic expressions, in their full configuration, were not observed at greater than chance levels within this meta-analysis (i.e., not observed in 87% of almost 4,000 participants across 69 experiments). Portions of each configuration (i.e., some but not all the facial movements in each proposed prototype) were observed as expected at greater than chance levels, but even so, these bits of expression were not observed frequently enough to be considered typical or representative expressions. Instead, most of the time, participants expressed instances of an emotion category with a wide variety of facial movements. For example, study participants partially scowled about 35% of the time during instances of anger, similar to experienced actors in the Le Mau et al. (2021) study, which suggests that scowling is *one* expression of anger in certain situations but is not a prototype, because a majority (65%) of the time, people were observed to express anger with other patterns of facial movements that share no family resemblance to scowling. Similar observations held for all the emotion categories included in both studies (and for similar findings in the spontaneous expressions in children, see Castro et al., 2018).[12] Specificity of expression was not assessed in the Durán and Fernández-Dols' (2021) meta-analysis because it was infrequently reported in the original articles, but is low when assessed, such as in the Le Mau et al.'s (2021) study of experienced actors (the highest specificity coefficient was, in fact, for scowling in anger at 0.52, corresponding to a false positive rate of 48%). Together, these findings do more than cast doubt on any view of biologically prepared emotion prototypes—they suggest that any category of emotion is expressed with a population of variable, situated facial movements, a hypothesis that was clearly reinforced by our unsupervised ML analyses (Le Mau et al., 2021).[13]

From Epistemology to Ontology

Let's pause to consider what we have learned so far. Numerous studies suggest that people around the world

[10] This study, like all studies, had limitations (e.g., still posed photographs were used, rather than dynamic movie clips, making it impossible to examine any information carried in the temporal dynamics of facial movements; the scenarios, photographs, and participants were drawn from a relatively uniform cultural context).

[11] One other sampling strategy bears mention because it also curates facial configurations in a way that is free from experimenters' beliefs about prespecified emotion categories. In this strategy, participants view random combinations of facial muscle movements and rate their emotional meanings (unfortunately, using choice-from-array). Called "reverse correlation," this method then statistically combines all of the facial configurations labeled with the same emotion word to estimate the mental representation (i.e., the concept) of each category's facial expression (for a review, see Jack & Schyns, 2017). There are some hidden constraints to the reverse correlation method as it is currently used (e.g., in addition to employing choice-from-array, faces are viewed in a contextless manner, and participants are assumed to possess only a single representation, i.e., a single concept, for each emotion category, making it impossible to test if a given participant may have multiple expression-related concepts for each emotion category, i.e., different representations for different situations). Nonetheless, the results again suggest considerable variation in people's expressive concepts for emotion. Another recent study using participants from the United Kingdom and China identified 62 separate concepts containing multiple configurations for a single emotion category within a given culture (Jack et al., 2016). These 62 concepts were also statistically summarized as four abstractions, which researchers interpreted as emotion prototypes: one corresponded to the hypothesized prototypic expression for happiness, the second corresponded to a proposed prototypic blend for fear and anger, the third corresponded to the proposed prototype for surprise, and the fourth corresponded to a proposed blend for disgust and anger (see Barrett et al., 2019, for discussion).

[12] A recent critique of the Durán and Fernández-Dols' (2021) meta-analysis (Witkower et al., in press) claims that emotions are, in fact, reliably expressed with the hypothesized prototypic facial movements. Witkower et al.'s conclusion rests on equating above chance effect sizes with strong reliability. They note that the average effect sizes reported in Durán and Fernández-Dols's analyses (for partial expressions), which are weak to moderate, are larger than the even weaker effect sizes routinely observed in personality and social psychology experiments. Witkower et al. fail to consider that weak to moderate average effect sizes leave significant room for false positives and false negatives when inferring a person's emotional state from their facial movements in the real world (for discussion, see Barrett et al., 2019).

[13] Not only did the Le Mau et al.'s study observe considerable amounts of situated variation in how experienced actors portrayed emotion with facial movements, but the emotional meaning of the context (i.e., the scenario) exerted a potent influence on the emotional meaning of its corresponding facial pose when participants viewed the two together. The emotion ratings of the scenario alone (from one sample of participants) better predicted the ratings of each pose presented with its corresponding scenario (i.e., faces in context, made by a second sample of participants) than did the ratings of the faces when viewed alone (from a third sample of participants).

reliably and robustly experience certain facial movements (physical signals) as prototypic expressions of certain emotion categories, provided certain contextual factors are in place, either alone or in combination. We discussed three of these factors: the sample of signals observed (Methods Issue 3), the manner in which they were observed (Methods Issue 2), and the response options that were permitted (Methods Issue 1). When these contextual factors are recognized and their constraints are relaxed or removed, scientists instead routinely, reliably, and robustly observe evidence of variation of a magnitude that is more akin to populations than prototypes, and emotional meaning that is functional because it is inherently situated and relational rather than biologically prepared: People around the world experience the same emotional meaning in a variety of facial configurations (i.e., as expressing instances of the same emotion category) and the same configuration of facial movements as having a variety of psychological meanings, not all of which are emotional in nature. This situated variation in what people perceive is also mirrored by situated variation in the movements that people make to express emotion. When taken together, this set of empirical observations cannot be easily squeezed into typological notions, no matter how persistent the effort. These observations call into doubt any view that enumerates a few dozen types of emotion, each supposedly composed of a prototype of physical signals, triggered by a unique collection of neurons, allegedly with inherent emotional meaning across situations, people, and cultures that can be merely tweaked by contextual influences.

In principle, no psychological scientist, not even someone who subscribes to strict typological thinking, would reject the existence of contextual influences. Typological approaches (which treat contextual factors as moderators) and fully relational views (in which the emotional meaning of any physical signal, such as facial muscle movements, is fully causally dependent on those factors) are better organized along a continuum rather than as a strict dichotomy (see online Supplemental Material Figure 1). Continuum or not, there remains an urgent need to resolve the century-long stalemate over the viability of a typological view of emotion in the face of robust, consistent evidence that pushes us toward a fully relational view. Without this consensus, the science of emotion has a serious validity problem (Barrett & Lida, in press). Ultimately, what is at stake here is nothing less than a frank assessment of our scientific knowledge about emotions and a reconsideration of how to best study them. So, what would it look like to seriously entertain the possibility that the informational value of any signal, such as the ability of one person's facial movements to convey emotional meaning to another person, is causally dependent and therefore conditional on an entire *ensemble* of factors in which those movements are made and observed? Not surprisingly, our entry point is a reconsideration of what psychologists call "context."

"Context" Reconsidered

As scientists, we understand that every experiment contains a multitude of factors that might influence our phenomenon of interest. Participants are tested at particular times of day in places with particular smells, temperatures, sights, and sounds. They arrive at an experiment with their own contextual factors, that is, a particular set of experiences and beliefs, having had particular amounts of sleep, having ingested particular amounts of food and caffeine, and having breathed air with particular concentrations of carbon dioxide, all of which could influence their metabolic dynamics. Participants interact with experimenters who themselves have particular beliefs, memories, sleep habits, and momentary physical states, tones of voice, facial and body movements, word choice, and so on. And participants register their responses using particular actions as prescribed by the experimental setup. It is tempting to assume the contextual factors that do not interest us scientifically are epiphenomenal (at best) or sources of outright error (at worst). In studies of emotion recognition, as we have just discussed, such factors are usually considered epiphenomenal to the inherent emotional meanings that facial movements are assumed to broadcast and therefore constitute moderators or even sources of noise in recognizing (i.e., detecting) said emotional meanings. As a consequence, attempts are routinely made to experimentally control these contextual factors by holding them constant across participants, by measuring their influence and statistically removing the variance they cause, by increasing sample sizes in an attempt to drown them out with the signal of interest, or by ignoring them and hoping the (error) variance they contribute will be randomly distributed across observations.

This approach—to control or reduce the impact of contextual factors rather than to model and analyze their causal influence—reflects a belief that a mind is a system of independent, separable mechanisms with precise laws of cause and effect, such that each mechanism can be studied individually without affecting the others. This assumption goes by many names in philosophy of science (the nuances in their similarities and differences are a discussion for another day). But they all conform to a "machine metaphor" (Lewontin, 2000) as a set of ontological commitments or a metanarrative about the nature of reality and the manner of scientific inquiry that is required to study that reality. The machine metaphor has its origins in the scientific revolution of Descartes and Newton, is associated with a reductionist approach to scientific inquiry, and remains a dominant philosophy of science in the writings and practices of psychological science. Types of perceptions, cognitions, emotions, decision-making, and so on are thought to be distinct psychological states, caused by distinct processes that are implemented in distinct populations of neurons which function in a law-like manner. It is assumed that, because they are independent of one another, cognitions, emotions, and the like can interact in their causal influence on behavior. Any factors that influence a phenomenon other than the process and neural circuit of the same name are assumed to be moderators or error.

Some scientists consider the machine metaphor and its associated epistemology to be one of the greatest accomplishments of psychological science, in the best tradition of the physical sciences. Others consider it an outdated view of physics and other physical sciences (e.g., Lewontin, 2000; Mayr, 2004), even going to far as to refer to it as an ideology grounded in Western individualism that biases scientific thinking (e.g., Lewontin, 1991). I started my career agnostic to the issue but, with the help of mentees and generous colleagues (some who educated me scholarly fields far from my own), I have increasingly questioned the ontological commitments of typologies in the science of emotion and more generally in psychology and neuroscience (e.g., Barrett, 2009, 2012, 2017b; Barrett & Russell, 2015; Barrett & Satpute, 2013, 2019; Lindquist & Barrett, 2012; Mesquita et al., 2010). Other like-minded scientists have raised similar questions in studies of development, motor movement, perception, social relations, psychopathology, concepts, consciousness, and many other domains, including basic brain functions that arise from dynamic relations among multiple, simultaneous, weak causal influences (for discussions and additional references, see, e.g., Buzsáki, 2019; Cisek, 2019; Eidelson, 1997; Fausto-Sterling, 2020; Gergen, 1978; Heft, 2001; Kirchhoff, 2018; Maturana & Varela, 2012; Mesquita, 2022; Mesquita et al., 2010; Russell, 2003; Smith et al., 2018; Smith & Thelen, 2003; Wright & Woods, 2020; Zelazo, 2013).[14] Again and again, experimental evidence calls the notion of types into doubt. Studies that do not usually *cannot*, in large part because they have been designed a priori to confirm their existence. Yet, modern day psychological scientists stand on the shoulders of philosophers and psychological scientists who repeatedly criticized the notion of typologies and the methodological designs they engender, pretty much since the dawn of psychological science, stemming back to William James's notion of the "stimulus situation" (again, see Gergen, 1978; Heft, 2001; Zelazo, 2013; and references therein; historical references related to the science of emotion specifically can be found in Barrett, 2017a; Barrett & Lida, in press).

Prior critiques have sometimes given rise to new scientific paradigms, such as ecological psychology, cybernetics-inspired dynamical systems approaches, and a variety of constructionist approaches (one of which we will return to later). Each effort is important and admirable in his own right, but none has sparked a scientific revolution on par with the downfall of typologies in other sciences, despite more than a century of discussion. This is no criticism of those efforts, but a testament to the difficulty of the task at hand. A conventional typological approach to psychological science, organized by cognitions, emotions, perceptions, motivations, and other Western folk psychological categories, reflects a particular, culturally specific theory of mind (Danziger, 1997). Since the professional and publishing institutions of psychological science are filled with people who likely possess and implicitly employ this theory of mind, we cannot, as a field, reconsider these most basic assumptions without also questioning our causal understanding of events in our own lives, akin to questioning our experience of gravity and the solidity of the objects we interact with. But question we must, because it is distinctly possible that, for a very long time, psychological scientists have misunderstood the nature of the very phenomena that we are attempting to understand. With this challenge in mind, let's strap on our seat belts and take the plunge. The goal here is not to offer answers to age-old mysteries, but to stimulate better scientific questions that have, in principle, a better chance of actually being answered. As in the first section of the article, we'll proceed through the lens of affective science.

Ensembles of Interwoven Signals

Let's start with the possibility that so-called contextual factors actually play a fully causal role in creating an instance of emotion or any mental event—even factors that are typically assigned to the so-called background. Here, contextual factors do not merely tweak the hypothetical, biologically prepared, psychological meanings of physical signals. They form a larger, complex web of causality: a dynamic ensemble of interactions that give rise to actions and from which psychological meaning emerges, but whose behavior is not predictable from its components in isolation. This complex system consists of many weak elements that interact, often nonlinearly, to produce outputs probabilistically.

A full exposition of complexity theory and complex adaptive systems is beyond the scope of this article, but discussions of complexity theory can be found in virtually every field within the natural sciences. In biology and other fields closer to psychology, for example, study after study has shown that a living organism is not an assemblage of separable mechanisms that can be studied bit by bit. Rather, contextual factors that may be weak on their own interact and coordinate in nonlinear ways to powerfully create phenomena that cannot be reduced to any weak factor in isolation. And importantly, it is not possible to manipulate one factor separately and leave the others unaffected. Therefore, modeling and analysis is more important than isolation and manipulation because reductionism is impossible in reality. Also, signals in nature are much more uncertain than

[14] The brain, for example, is thought to function like a complex adaptive system whose behavior emerges from the intricate interaction of neurons, glial cells, vascular, metabolic and chemical elements, their internal dynamics, and their interaction with elements of the environment (both the internal environment to which a brain is attached, i.e., the rest of the body, and the external environment outside the skin; e.g., Bassett & Gazzaniga, 2011; Bressler & McIntosh, 2007; Favela, 2020; Kelso, 2012; Krubitzer & Prescott, 2018; Sporns, 2011; Tononi & Edelman, 1998).

is assumed in a typological approach, so we must acknowledge the uncertainty and try to discover and model its structure.

How might our understanding of emotion, or more broadly, psychological events of any kind, change if our experimental inquiries assumed that every behavior, every experience—every mental event—arises from such a web of complex causation? For a start, complexity theory reinforces our earlier observation that surrounding signals (i.e., contextual factors) might be considered part of the web of causal forces that are at play in any laboratory experiment. A growing number of studies give evidence of the profound and surprising ways in which so-called contextual factors influence psychological events, even when those factors are studied in isolation (e.g., time of day, Hahn et al., 2012; odor, Leleu et al., 2015; Sorge et al., 2014; CO_2 concentration, Scully et al., 2019; sleep quality, Prather et al., 2013; heart rate, breathing, and other conditions of the body, Al et al., 2020; Galvez-Pol et al., 2020; Grund et al., 2022; Kluger et al., 2021). It is well established that contextual factors influence even the most basic aspects of movement perception and object perception (e.g., Bar, 2004; Brandman & Peelen, 2017; Castelhano & Pereira, 2018). Even whether a participant saccades to a stimulus versus passively views a stimulus is associated with different signal patterns in primary visual cortex (e.g., MacEvoy et al., 2008; Zirnsak & Moore, 2014). In psychology experiments, these and other potentially impactful influences go unmeasured most of the time, producing variation that masquerades as error. As a consequence, the modest effect sizes in psychological research may, in part, be a consequence of mistakenly trying to model complex phenomena as a simple, linear mechanistic systems (Barrett, 2020a, 2020b). Notions of complex causation suggest the need for experimental designs that seek to discover and model structured variation, with the potential to forge a more robust and replicable psychological science.

Also consider that many of the "contextual" signals that are most relevant to any mental event are found *in a person's brain*. A brain does not detect features in the world and body; a brain *assembles* features as ensembles of interwoven physical signals to create meaning. Some features are closer in detail to the raw sense data coming from the sensory surfaces of the body and that guide organ function, metabolism, immune function, and muscle fiber contractions (i.e., features that are higher in dimensionality). Some are more abstract (lower in dimensionality); these are mental features, such as "goal," "value," "threat," "reward," "valence," "arousal," "novelty," and so on. Mental features are compressed, multimodal summaries of the sensory and motor signals (as discussed in Barrett, 2017b; Katsumi, Kamona, et al., 2021; Katsumi, Theriault, et al., 2022). A word for a psychological category, such as anger, might be thought of as an efficient way to communicate an entire pattern or ensemble of features without listing them individually. An important hypothesis here is that sensory signals originating in the world are not the only, nor even the primary, source of the "contextual" signals that participate in creating meaning. Some originate in the body, and some (the compressed, multimodal summaries) are only found in the brain. Moreover, signals are continually generated intrinsically within the brain as it converses with the body and the world, reassembling past events that are *similar* to the present in some way (i.e., the brain constructs features of equivalence; for discussion, see Barrett, 2017a, 2017b). These features of equivalence are the means by which a brain generalizes from the past to regulate the internal systems of the body, guide action and create experience, and in the process give psychological meaning to sensory and motor signals of higher dimensionality. The result is what the neuroscientist Gerald Edelman referred to as "the remembered present" (Edelman, 1989). Sensory signals originating in the world and in the body are hypothesized to constrain and shape the brain's intrinsic signals (i.e., the brain's internal dynamics), serving to select or correct the signal ensemble that will constitute the next mental event.

This hypothesis implies that the nature of emotion will never be revealed by measuring only facial muscle movements, changes in autonomic nervous system activity, or the brainstem circuitry that supports running, freezing, or any other skeletomotor action. Nor will the nature of attention be revealed by only measuring signals in the prefrontal and parietal areas in the cerebral cortex (e.g., Gonzalez-Castillo et al., 2012). This is because psychological meaning is not contained in these signals alone. Any mental event arises as an ensemble of interwoven signals that includes abstract, multimodal compressed summaries (Barrett, 2009, 2012, 2017a, 2017b; Barrett & Lida, in press). (This hypothesis is consistent with appraisal views of emotion, in which appraisals are mental features that describe a person's experience of themselves in a particular situation; Barrett, Mesquita, et al., 2007; Clore & Ortony, 2013.) Accordingly, a rigorous epistemological strategy will require that scientists cast much wider observational nets than is currently the norm if we hope to ever understand the physical basis of any psychological phenomenon.

If psychological meaning arises within a complex system of many weak, nonlinear, interacting causes, some of which are found only in the brain of a perceiver, then perhaps when you experienced terror or elation in Serena Williams's furrowed eyebrows, pinched eyes, and gaping mouth, you were not recognizing an emotional display. Instead, you were *constructing* it. Your experience emerged as a system-level event, the product of signals that derive their psychological meaning within a complex, dynamic system of other signals, including the signals in your brain and the context you carry around with you (e.g., the state of your own body). There is also a broader spatio-temporal context (e.g., Where are you located? What time of day is it? What led up to the present moment? What might happen in a moment from now?), all embedded in a broader cultural context. In the real world, one rarely encounters a disembodied face like the floating Wizard of Oz in the Emerald City. Real faces appear in rich, dynamic, multisensory, temporally extended contexts. They usually appear on heads that utter words with vocal prosody, are attached to bodies that move in certain ways and carry certain smells, and are associated with other surrounding details. Such dynamic spatio-temporal arrays are the natural ecology in which we experience everything, including the emotions that we see (and hear and feel) in others. Facial movements are made psychologically meaningful in those signal arrays within your brain, your body, and the external context. Signals interact with one another in probabilistic ways to create a mental event, such as whether you experience the rise of an eyebrow or the curl of a lip as an expression of someone's emotional state or as noise to be ignored. Together, these causal factors create a constantly changing web of influence that adjusts to the present situation using what is learned from vast arrays of past experience.

It remains to be seen whether complexity theory is a worthy ontological guide for the science of emotion and psychological science more generally. In the practice of science, the devil is in the details, and there are a lot of details to consider. Adopting these commitments suggests that we should design our experiments to consider a range of weak, interacting influences, including even those factors that are not of central interest, in an effort to gain explanatory power. If your head is shaking as you read these words and consider the pragmatic nightmare that I am suggesting, then it is mirroring my own as I write this. I don't have to tell you that designing and implementing such studies will be a bitch (i.e., expensive, time-consuming, and frankly frustrating). To study ensembles of interwoven signals, including those that are within the brain of a perceiver, requires a scientific approach that investigates any mental event as something that emerges from a system of signals as a whole, in interaction with the signals that impact the system. We will need to specify which elements are part of the system and which are inputs and outputs (e.g., Are physical signals from the body part of the complex system that gives rise to mental events, or are they inputs to the system? Are the physical signals coming from an interaction partner better modeled as part of the complex system, or should they be modeled as inputs to a system that is bounded by the skin of a single person?). We might want to model the internal dynamics of the system over time without any inputs (a task that is complicated by the fact that a living, dynamic brain is permanently attached to a physiologically dynamic body), as well as how the system is impacted by inputs over time. We will have to upend familiar policies and practices that guide the professional aspects of our science, train our students differently, and secure resources that might not yet be available. But complexity theory is still worth our curiosity as a viable basis for reconceptualizing what a mind is, how it is caused, and what its causal powers might be. In particular, these ideas let us explore whether the phenomena that culturally constitute a particular version of the human mind—with various cognitions, emotions (both their generation and their perception), and the like—emerge from more basic, domain-general causal processes that are shaped by evolution, development, and ecology. These domain-general causal processes might also account for the variety of mental categories that have been observed in other cultures, as well as individual differences in the granularity of categories that constitute a human mind (e.g., Barrett, 2017a; Hoemann, Khan, Feldman, et al., 2021; Hoemann, Nielson, et al., 2021; Kashdan et al., 2015; Wilson-Mendenhall & Dunne, 2021) On the other hand, if we continue to insist, as a field, that reliable and generalizable observations will result from isolating and manipulating a couple of variables and their interactions as long as we tighten our methodological belts and improve our experimental rigor, then we are fooling ourselves.

Relational Meaning

Thus far, we have considered the possibility that psychological phenomena emerge as complex ensembles of time-varying, interwoven signals, some that reside in the surrounding situation and in your body, and some that are constructed in your brain to model the world and your body, including abstract, multimodal features referred to as mental features. An unsettling yet far-reaching implication of this hypothesis is that the psychological meaning of any physical signal exists *only* in relation to the rest of the ensemble, a web of variation in other physical signals. In other words, *physical signals may have no inherent psychological meaning*. Rather, meaning is constructed as relative information with respect to other signals, including those in a human brain that can remember (i.e., reassemble) features from the past. In a relational view of meaning, any physical signal of interest in the science of psychology—heart rate variability, skin conductance, glucose metabolism, cytokine concentrations, dopamine, serotonin, and norepinephrine release and uptake—has no biologically prepared, perceiver-independent psychological meaning. Even the electrical activity in a population of neurons has no inherent psychological function. The meaning of any neural signal is always in relation to other physical signals (including those in the rest of the brain, e.g., McIntosh, 2004), most especially the other neurons receiving that neuron's action potentials (e.g., when a single pattern of action potentials from a single neuron is received by a motor neuron, it is considered a motor signal; when the same action potentials are received by sensory neurons, they are considered sensory signals).

By implication, facial movements like smiles, frowns, scowls, and other physical signals may not have evolved, inherent meaning as emotions. We hypothesize that a scowl becomes meaningful as an expression of anger only in particular contexts that include the brain of a person with particular past experiences that are reassembled in the present. A scowl can also meaningfully signify heartburn or the enjoyment of a pun, depending on how the facial muscle movements are categorized (i.e., which memories were reassembled to construct the action plan and other abstract, mental features that helped give meaning to the movements). Serena Williams's furrowed eyebrows, pinched eyes, and gaping mouth, as physical signals, took on emotional meaning for you only in relation to an ensemble of other physical signals, some of which emerged only in your brain as part of this meaning-making process. Goals, value, affect, and other mental features are not properties that exist in the world or the body. They are features that exist only in a brain that creates these relational ensembles.

Correspondingly, we hypothesize that Williams's brain, after her victory over her sister Venus in the U.S. Open (or even milliseconds before), assembled a population of possible signal ensembles from past instances that shared some feature or features of equivalence (e.g., her brain may have constructed a situated, conceptual category for elation from past instances of elation); each signal ensemble included the features to guide upcoming actions (e.g., upcoming facial movements) and create experience, including mental features that only exist in her brain. Incoming sensory signals then selected one ensemble to construct a situated instance of elation. This selection, in effect, completed a categorization that made the physical movements of her face (along with the other physical signals emerging from the selected action plan) meaningful as an instance of elation. In our lab, we hypothesize that the psychological meaning of physical movements is constituted by this relational meaning-making process, not determined by it. Through this lens, emotional communication, or communication of any sort, is not detection of biologically prepared, inherent meanings, but is a synchrony of relational meanings across interacting brains (e.g., Gendron & Barrett, 2018; Nguyen et al., 2021; Nozawa et al., 2019).

Relational meaning—the hypothesis that physical signals only have meaning in relation to other physical signals, some of which are only in a brain—is unintuitive and perhaps discomforting in its implications, but it is not "extreme relativism." It is a hypothesis that psychological meaning arises as a complex web of interdependent signals that necessarily involves you as well as other people. It is a realism that is consistent with our evolved roles as social animals, as well as our ability to collectively create social reality and then transmit that reality to others via acculturation and cultural inheritance (Barrett, 2012, 2017a, 2017b; Barrett & Lida, in press). This realism differs from the usual dichotomy drawn between idealism (reality exists in your head) and materialism (reality exists in the world). It suggests that to properly understand a psychological phenomenon, such as an expression of emotion, scientists must measure more than just facial muscle movements or vocalizations. We must also measure the signals that give those physical signals their psychological meaning. That is, the "relative information" shared between signals (Shannon & Weaver, 1964) must be observed and modeled (for examples of studies of emotion recognition that use information theory, see, e.g., Jack & Schyns, 2017).

Population Thinking

If instances of emotion and other mental events emerge in a complex web of causal factors full of relational meaning, and we design our experiments accordingly, then we have a combinatorial explosion of possible patterns. In the words of the evolutionary biologist Richard Lewontin, "Organisms are … extremely internally heterogeneous. Their states and motions are consequences of many intersecting causal pathways, and it is unusual that normal variation in any one of these pathways has a strong effect on the outcome … Indeed, we may define 'normality' as the condition in which no single causal pathway controls the organism … All attempts to understand causes must necessarily involve the observation of variations" (Lewontin, 2000, pp. 93–94). Simply put, variation is the norm. Different sets of sensory-motor signals can, in different situations, co-occur with the same (or highly similar) compressed, multimodal signals that create abstract, mental features. Conversely, a single ensemble of sensory-motor signals can co-occur with different mental features in different situations. The possible variety is not limitless, but it is considerably greater than what is hypothesized by typological views of the mind. Attempts to understand the causes of emotion, or any psychological phenomenon, will be hampered if nonrigorous sampling of participants, stimuli, and measurements limits this variation, as we observed earlier in ML studies of emotional expression.

The variation that is typically assigned the role of error or moderator in any given study may be structured in reliable, predictable ways, as demonstrated by the Le Mau et al.'s (2021) study of actors' portrayals. In another recent study that was designed a priori to capture structured variation (Hoemann, Khan, et al., 2020), we predicted and observed (via unsupervised ML) that patterns of physiological activity (i.e., physiological motifs) for an emotion category varied in context-dependent ways within an individual participant. Instances of a given emotion category, such as anger or happiness, showed a considerable amount of variation in a given participant's physical and mental features. Furthermore, the study supports our hypothesis that reliable patterns of physiological signals have no inherent emotional meaning; a given motif was made meaningful as a variety of emotions, again, across situations within an individual participant.

Historically, multiple physiological motifs have been observed for a given emotion category across studies, and there is substantial overlap of motifs across different emotion categories (for recent meta-analysis of this literature, see Siegel et al., 2018). That is, scientists have been unable to identify a physiological prototype for any emotion category that is sufficiently specific and reliable across studies, despite decades of search for emotion-specific physiological motifs. The Le Mau et al. (2021) and Hoemann, Khan, Feldmsn, et al. (2020) studies and others like them suggest an interpretive frame for this tangle of observations: A given emotion category is created as multiple, situated patterns; in fact, an instance of a given category could have multiple motifs in the same situation (this is called degeneracy; e.g., Edelman & Gally, 2001).

A similar situation exists with brain imaging studies of emotion. In the last decade, numerous studies employing supervised ML approaches have searched for the prototypic pattern of brain signals corresponding to a specific emotion category, such as fear, which is subsequently interpreted as the brain biomarker for that category (e.g., Zhou et al., 2021). The identified patterns, however, differ across published studies (e.g., Horikawa et al., 2020; Kassam et al., 2013; Kragel & LaBar, 2015; Saarimäki et al., 2016; Wager et al., 2015; Wilson-Mendenhall et al., 2015) and might instead indicate the presence of meaningful, structured variation, a hypothesis supported by brain imaging studies that have documented variation in the neural correlates of different instances of emotion within the same emotion category (e.g., Lebois et al., 2020; Wilson-Mendenhall et al., 2011, 2015). We have also applied various unsupervised ML models to discover this structured variation in brain imaging data during emotional experience when no a priori labels are applied to the data (Azari et al., 2020; also see Doyle et al., 2022). Even participants watching the same video clip have substantial variation in their brain signals and state dynamics (Singh et al., 2021; see also Chang et al., 2021). Our findings again suggest that emotion category labels refer to populations of variable, context-specific instances that would be better sampled and modeled using methods suitable for estimating structured variation (also see Boiger et al., 2018). Such an approach would allow scientists to discover, rather than presume, conditions when such variation might generalize across situations, people, and cultures.

Fortunately, Darwin (1859) gave us a conceptual tool for thinking about this magnitude of structured variation. It is called population thinking, named by the evolutionary biologist Ernst Mayr (e.g., Mayr, 2004). Population thinking, as articulated in *On the Origin of Species*, refers to the idea that a biological category, such as a species, is a conceptual category of individuals with variable physical features, and whose fitness is inherently relative to the conditions of the immediate environment. William James adapted Darwin's observation to the nature of emotion over a century ago: "The variety of emotions are innumerable," James wrote in 1961 (p. 241). "The trouble with the emotions in psychology is that they are regarded too much as absolutely individual things. So long as they are set down as so many eternal and sacred psychic entities, like the old immutable [pre-Darwinian] species in natural history, so long all that can be done with them is reverently to catalogue their separate characters, points, and effects" (James, 1998, p. 449; italics in the original)" And James continued, "But if we regard them … as 'species' are now regarded as products of heredity and variation, the mere distinguishing and cataloguing becomes of subsidiary importance" (James, 1998, p. 449). Since then, population thinking has been periodically revisited in psychological science a number of times, although sometimes under different names (e.g., Estes, 1956; Gallistel, 1980, 2012). Our hypothesis—that any psychological category, and correspondingly, any biological category, including any emotion category, is a population of situation-dependent instances with variable features—is similarly inspired by this Darwinian idea (as discussed in Barrett, 2013, 2017a, 2017b, Barrett & Lida, in press; Clark-Polner et al., 2017; Siegel et al., 2018).

In population thinking, variation among a category's instances is assumed to be real in nature, structured, and meaningfully related to the situations in which those instances emerge. Any abstract summary of a category, such as its mean or a prototype, is a fiction. (By analogy, the average U.S. household size in 2020 was 2.53 people, but no real family contains 2.53 individuals.) ML analyses that search for a single pattern to summarize multiple participants are, in effect, searching for an abstraction that need not exist in any individual participant's data; e.g., in any given brain imaging study, the so-called biomarkers for emotions are actually abstractions (per population thinking), not actual brain states (per typological thinking; for a mathematical simulation, see Clark-Polner et al., 2017). When viewed through the lens of population thinking, the proposed expressive prototypes for each emotion category—smiling in happiness, scowling in anger, frowning in sadness, and so on—are stereotypes (Barrett et al., 2019). They are oversimplified beliefs about emotional expressions that are taken to be more applicable and diagnostic than they actually are.

As a scientific tool for psychological science, population thinking is enriched by the discovery of ad hoc conceptual categories (Barsalou, 1983; Barsalou et al., 2003; Casasanto & Lupyan, 2015). Categorization is the grouping of objects or events according to their similarities (Murphy, 2002). Similarities are features of equivalence. The similarities shared by a category of instances need not be physical; they can be mental, defined in relation to the categorizer's goals in a specific situation (that is, the particular function the instances serve for the categorizer in a specific situation). For example, the categories "flower" and "weed" are defined functionally, not physically. A bright yellow dandelion with green leaves might be categorized a nasty weed to pluck from a garden, a beautiful flower to place in a vase of wildflowers, or even a nutritious food to eat in a salad, depending on a person's goals in a particular situation (Barrett, 2012). Likewise, the movement of "scowling" is a situated conceptual category because its instances are created by physical changes that vary across instances and people (i.e., individual differences in facial anatomy and the brain's control of facial muscles cause varied execution at the muscular level, even when facial movements look the same to the naked eye; for discussion, see Barrett et al., 2019, online Supplemental Material Box 5; and references therein). Even the physical signals that become sounds (Barsalou, 1992) and smells (Cleland & Borthakur, 2020) are processed as conceptual categories. From this perspective, a brain's assembly of physical signals, some of which are abstract mental features, can be thought of as situated conceptual (or ad hoc) category construction (as sketched in the section on *Relational Meaning*).

Our research program studies emotion categories as situated, ad hoc conceptual categories (Barrett, 2006, 2017a, 2017b; Lebois et al., 2020; Wilson-Mendenhall et al., 2011, 2013, 2015), predicting and observing the variation reviewed earlier in this article. We hypothesize that as a brain continually assembles features of equivalence (i.e., similarities), which are part of larger ensembles of interwoven physical signals, it is actually constructing a situated conceptual category, such as an emotion category, that is tailored to goals and functional requirements that are situation-specific. In a human brain, instances of the same category need not have similar sensory and motor features (i.e., instances of anger need not involve the same changes in blood pressure, respiration, physical actions); the features of equivalence that make the instances similar in a particular situation can be abstract, mental features (i.e., the lower dimensionality, compressed, multimodal summaries). A single abstract mental feature, or a single pattern of abstract features, can be associated with variable sensory and motor features for controlling the body and creating experience (i.e., with an entire distribution of possible neural assemblies that we call a situated category). These variable patterns of sensory and motor features each have some probability of fitting the present situation (i.e., a prior probability) based on similarity to past experiences that also contained the abstract features of equivalence; that is, by virtue of their shared abstract feature(s), different sensory and motor signals share the same (relational) psychological meaning in a specific situation (where a situation is defined as anything going on outside the brain, i.e., in the body and the world). The pattern with the best match to the current situation gives meaning to sensory and motor signals of higher dimensionality, in effect categorizing them. That is, the features of equivalence are the means by which a brain generalizes from past experiences to categorize incoming sensory signals and outgoing motor signals, giving them psychological meaning in a specific situation as a brain regulates the body, guides action, and creates experience. In our lab, we have hypothesized that *the brain's continual, situated category construction creates all mental events* (Barrett, 2017a, 2017b; Shaffer et al., 2022). Cognitions, perceptions, motivations, and the usual psychological phenomena named in the tables of contents of introductory textbooks (and the pages of journals like this one) might be considered ad hoc events that are assembled across the whole brain, not states that exist in distinct territories of neurons. Features of equivalence have a dimensionality that we hypothesize is linked to the granularity or situatedness of a person's actions and experiences. A brain that relies *only* on lower dimensionality, abstract features of equivalence (e.g., negativity, threat, or reward) may be a brain that risks overgeneralization, context-insensitivity, experiences that are low in granularity and poor episodic memory (e.g., in depression; Shaffer et al., 2022). At the other end of the spectrum, a reliance on higher dimensionality sensory and motor features of equivalence to the exclusion of lower dimensionality, multimodal abstractions is a brain that may struggle insufficiently flexible and overly situation-specific experiences and actions (e.g., in autism spectrum disorder; Barrett, 2017a).

The implication is that *every category is a situated event* with no static, perceiver-independent prototype (for more on the view of situated conceptualization as a process, see Barsalou, 1987; Barsalou et al., 2010; Casasanto & Lupyan, 2015; Spivey, 2007). Its features of equivalence are always constructed by a particular perceiver for a particular function in a particular situation. The summary of any ad hoc, situated category is analogous to a prototype that best suits the functional goal of the categorizer in that specific situation (Barsalou & Hale, 1993; Voorspoels et al., 2011). For a given perceiver, a given emotion category therefore has as many prototypes as there are different functional contexts or situations for that perceiver. Fear of starving in the woods, as a situated conceptual category, may have a different prototype for a given perceiver than fear in a haunted house, fear of being stung by a bee, fear of being rejected by a lover, or fear of accidentally harming a friend. Accordingly, that perceiver might cry in fear, laugh in fear, startle in fear, hug someone in fear, or even fall asleep in fear, whatever action their brain has learned to construct to mitigate threat in a given situation; and the corresponding physiological motif that supports each action varies accordingly (Obrist, 1981; Obrist et al., 1970). The same physical signals therefore have relational emotional meanings that can vary by situation and person. And two people who live in the same culture will learn to construct similar situated prototypes (i.e., similar ensembles of entwined, related physical signals), allowing them to communicate efficiently and effectively.

At this point, you might ask, "Amidst all this variation, what makes instances of fear what they are—fear—and not some other kind of emotion?" If so, you are asking a typological question that is not meaningful in population thinking. Across the entire population of fear instances for all creatures whose brains are equipped to make instances of fear, the features of equivalence (i.e., the similarities that create an ad hoc conceptual category for fear) can be person- and situation-dependent, resulting in variable patterns of features.

Ultimately, population thinking changes the questions we ask about psychological phenomena. We would not ask questions about the nature of fear, or any psychological category, as if it is a third-person phenomenon that happens independent of person and spatio-temporal context. Instead, we ask questions about how features of equivalence are chosen and constructed; how a brain continually constructs categories; how categorization proceeds; how bodily regulation, actions, and experiences emerge within this ongoing construction process; what conditions produce similar prototypes across situations and people to allow for communication and category learning; and so on.

Constructionism

The ideas that we have been discussing—ensembles of interwoven signals, relational meaning, and population thinking—are consistent with a philosophy of science called natural constructivism (Gleiser, 2015). They also bear a family resemblance to other systems of ideas, including William James's radical empiricism (1996); ecological psychology (e.g., Heft, 2001 and references therein); grounded cognition (e.g., Barsalou, 2008); complex dynamical systems approaches to development (e.g., Zelazo, 2013 and references therein); the social cognition hypotheses of situationism, construal, and dynamic tension systems (Ross & Nisbett, 1991); and what is now being called "radical embodied cognitive neuroscience" (Raja & Anderson, 2019). These ideas are also consistent with a variety of constructionist approaches to emotion.

The psychologist George Mandler first named "constructionism" as an approach to the science of emotion in his 1984 book, *Mind and Body: Psychology of Emotion and Stress* (in a section titled "The Construction of Emotion"; Mandler, 1984; see also Mandler, 1990), but nascent constructionist ideas can be easily traced back from early to mid-20th century to the 19th century, with historical tendrils reaching back even further (Barrett, 2017a; Gendron & Barrett, 2009). In the modern era, a constructionist perspective to emotion was synonymous with social constructionist views until psychological construction was introduced in 2003 by the psychologist Russell (2003). In a social construction view, instances of emotion are hypothesized to derive from social and cultural ingredients (i.e., cultural artifacts), including social roles, beliefs, values, other people's actions toward you, and various sociocultural structures (e.g., Averill, 1980; Boiger & Mesquita, 2012; Harre, 1986; for a historical and anthropological overview of social constructionism, see Reddy, 1997). Psychological construction views propose that the ingredients of emotion are psychological processes: Emotional instances are hypothesized to arise from affective feelings when they are categorized, conceptualized, or otherwise made meaningful as emotions with some sort of mental mechanism (e.g., Cunningham et al., 2013; Lindquist, 2013; Mandler, 1984; Russell, 2003; also see Barrett & Russell, 2015).

I have been developing a multi-level constructionist approach with mentees and collaborators for three decades, first as the conceptual act theory (Barrett, 2006, 2012), which developed into the theory of constructed emotion (Barrett, 2017a, 2017b) and has now been expanded to the constructed mind approach (Shaffer et al., 2022). Ours is a multidisciplinary approach to understand how mental events (including actions) arise within a brain that is in continual, dynamic conversation with its body and the surrounding world. The specific hypotheses and evidence for this approach have been fleshed out in additional published articles (e.g., Barrett & Finlay, 2018; Barrett & Lida, in press; Barrett & Satpute, 2019; and references below). Some details of our approach were alluded to earlier (the specific details are beyond the scope of this article), but four key hypotheses are worth revisiting.

Prediction

Our approach hypothesizes that situated category construction, which occurs automatically and continuously through an individual's life, proceeds via prediction, selection and correction, together known as predictive processing (see these articles and references therein; Barrett, 2017b; Barrett & Simmons, 2015; Chanes & Barrett, 2016; Hutchinson & Barrett, 2019; Katsumi, Kamona, et al., 2021; Katsumi, Theriault, et al., 2022). Each mental event begins as a category, constructed as an ensemble of interrelated, temporally evolving physical signals across the entire brain. These signals constitute patterns of possible features from combinations of past experiences that the brain believes are similar to the present in some way (i.e., features of equivalence). These prediction signals are continually checked against incoming signals from the body's sensory surfaces (both in and on the body). Incoming sensory signals, along with attentional signals called "precision signals," help to select the pattern of signals (of features) that will coordinate motor actions and conscious experience. The incoming physical signals hitting the sensory surfaces of your body have no inherent psychological meaning. They, and the signals that control motor actions, are made meaningful—categorized—in relation to the signals in the brain. Mental features are experienced as explaining actions and their associated sensations. When unexpected signals arrive from the sensory surfaces or expected signals do not materialize, collectively called "prediction errors," a brain has an opportunity to correct its predictions (known as "learning"). Predictive processing, when understood as continuous category construction, offers a coherent, neurobiological research framework to unify many proposed constructs for how a brain creates relational meaning, such as appraisal, construal, generalization, memory, perceptual inference, conceptualization, simulation, latent cause inference, and categorization.

Coordination and Regulation of Bodily Systems

Our approach also hypothesizes that psychological meaning is rooted, fundamentally, in the brain's predictive regulation of the body, called allostasis (Sterling, 2012; for a discussion of some of the neuroscience hypotheses, see, e.g., Barrett, 2017b; Katsumi, Kamona et al. (2021); Katsumi, Theriault et al. (2022); Kleckner et al., 2017; Sterling & Laughlin, 2015; for modeling details, see Sennesh et al., 2022). This hypothesis is consistent with evolutionary approaches to understanding nervous system function, in which the fundamental function of a brain is not to build knowledge about the world but to efficiently control an animal's energetic state and coordinate its bodily systems as it navigates its niche (e.g., Cisek, 2019). From this perspective, every situated, conceptual category, such as an ad hoc category for fear, begins as abstract, mental features that include an abstract action concept or intention—a descending cascade of potential motor patterns to control the systems within the body (e.g., the autonomic nervous system, immune system, endocrine system) that support movements of the body (i.e., the skeletomotor system).

Action Creates Experience

The dynamics of predictive processing suggest that action preparation gives rise to experience, not the other way around. During conceptual category construction, prediction signals that prepare motor action simultaneously cascade to simulate the expected sensory consequences of the expected motor movements (called an efference copy or corollary discharge). This hypothesis runs counter to typological views, which hypothesize that your brain detects events in the world and constructs a perception, then evaluates the perception to create a cognition or emotion or some interaction of the two, which then results in an action plan. We hypothesize instead that perception and experience arise *from* predicted actions, rather than causing those actions, and experiences and actions are always constructed with respect to predicted future energy (allostatic) needs.

Cultural Inheritance

Our approach also hypothesizes that cultures play a role in transmitting psychological meanings (i.e., conceptual categories) from one generation to the next (Barrett, 2017a; Lindquist, Jackson et al., 2022). This runs counter to the standard hypothesis of evolutionary psychology, in which humans evolved particular signals, such as facial movements, physiological changes, or even patterns of neural firing with particular genetically encoded psychological meanings.[15] Our hypothesis is strengthened by growing evidence that humans are born with our brains under construction (e.g., Gao et al., 2017; Gilmore et al., 2018; Grayson & Fair, 2017; Zuo et al., 2017), and some of our genes allow our brain development to be biologically shaped by (and coupled to) features of the environment (including the social environment). Signals from the physical world, including those arising from social behaviors, are necessary inputs for a human brain to develop the capacity to model its body as it moves around in the world, including the construction of abstract mental features. During development and the processes that scientists call "socialization," the words (Gelman & Roberts, 2017) and actions of others (e.g., Atzil et al., 2018; Gendron, Mesquita, & Barrett, 2020; Mesquita, 2022) create recurrent situations that allow a brain to learn specific, situated meanings of particular signals in the natural and cultural ecology of a person's environment. This arrangement creates opportunities for cultural inheritance (e.g., Boyd et al., 2011; Richerson & Boyd, 2008) to transfer knowledge across generations. As human brains develop, they grow the micro-wiring to construct culturally relevant mental features, including their attentional capacities for deciding which signals are relevant and which are noise to be safely ignored. (An obvious example is the ways in which a young brain tunes and prunes with experience to hear certain speech sounds while losing the capacity to hear others).

In this way, a human brain develops the wiring to model its body and the world it inhabits. It becomes encultured with the knowledge to create meanings that are relevant to a particular set of cultural practices and values. As children develop into adults and interact with their world, they create some of the signals in the environment (by their words and actions) that serve as wiring instructions for the brains of the next generation. We hypothesize that evolution produced a human brain architecture with the capacity for flexible, situated meaning-making that can be synchronized across minds and across generations. This capacity comes at a cost, however. Without the physical signals from the world, a brain does not receive the necessary wiring instructions to develop and function in a

[15] Typological views typically draw from an evolutionary theory (called the modern synthesis) in which genes transfer information from one generation to the next, usually by way of specific, inborn circuits that are thought to be adaptations, localizing different psychological phenomena to different parts of the brain.

neurotypical fashion (e.g., McLaughlin et al., 2019 and references therein).

Scientific Validity

These entwined ideas of complex signal ensembles, relational meaning, and population thinking have many important implications for how we understand our work as practicing scientists. I will mention just a few here.

Humans Versus Nonhuman Animals

When viewed through the lens of relational meaning, all brains form situated concepts to categorize anticipated sensory inputs and guide action. What differs among species, from this perspective, is the degree of abstraction that a brain can support—the degree of signal compression in the features that are constructed—not the computational principles that govern their construction. These differences result from general brain-scaling functions (Workman et al., 2013) and the information available in an animal's niche. For example, the human brain has expanded association cortices in the frontal lobes, parietal cortex, and inferotemporal cortex compared to other primates, including other great apes (Sherwood et al., 2012, 2017), along with metabolic and neuropil changes in the upper layers of cortex (see Theriault et al., 2021 and references therein). This expansion potentially allows for increased signal compression and dimensionality reduction, suggesting that human brains are capable of multimodal summaries (i.e., features) characterized by greater abstraction (see Finlay & Uchiyama, 2015; Katsumi, Kamona, et al., 2021). This hypothesis has important implications for how to generalize observations of non-human animals to humans.

Who Is Constructing What?

It is common for human scientists to observe a fly freezing, a rat running, and a human gasping with a wide-eyed stare and conclude (categorize) that all three animals are in a state of fear, functionally defined by the goal to escape, avoid or protect against threat. A neurotypical human brain can construct such a category with ease, despite the vast physical differences in the three events, because it can compress signals into an abstract feature of equivalence that creates this similarity (in this example, the goal). Now consider fly brains and rat brains—are they architecturally equipped to compute such abstract features? If a fly beneath a looming fly swatter rubs its legs together on one occasion but freezes on another, a human brain can generalize across both cases to experience the fly as being in a state of fear. But are fly brains equipped to go beyond physical features and generalize from one situation to the other? If not, then in whose brain does this state reside? (Hint: It is not the fly's or the rat's.) This is my point when I describe instances of emotion and emotion perception as first person, perceiver-dependent events, not third-person, perceiver-independent phenomena (Barrett, 2012). A fly's fearful state is real for human scientists, but perhaps not for the fly whose brain may not be capable of computing abstract features like "a goal to protect against threat" when making sensory signals meaningful in the service of action in a specific situation. Even perceiving an animal as "running" is, in fact, an abstraction from briefer, more basic (and perhaps innate) muscle motifs that can be flexibly assembled in a specific situation (in relation to the signals therein; e.g., Datta, 2019). Such notions call into question the "perceiver-independence" of functional views of emotion and the mind that confuse scientific consensus with objectivity.

The Importance of "Context," Again

An animal's body and its ecological niche are as important to the nature of its mind as the circuitry in its brain (and they help determine the sorts of meanings that its brain can compute). Such observations reinforce the importance of studying mental phenomena in the wild, rather than in traditional laboratory settings, or to create laboratory settings that are similar in complexity to the real world. Anything you learn about the mind from an experiment is constrained by the experimental setting. Watching a film clip while lying flat on your back, completely still in the bore of a large magnet, is not at all like strolling across campus with a friend in the early morning while sipping tea, confronting your boss in a board room with glaring lights and too much air conditioning, or lying in bed with your lover in the middle of the afternoon. As these examples imply, there is a crucial need to measure the state of a participant's body (and their brain's modeling of that body), even when studying psychological phenomena that you believe are purely cognitive and having nothing to do with the body, such as cognitive control (e.g., Kragel, Bianciardi, et al., 2019).

The Credibility of Psychological Research

When a study's findings do not replicate, the usual assumption is that the first study was flawed or the proposed mechanistic cause was not sufficiently robust. (Or perhaps that professional pressures of organized science have led to a "creative" use of statistics.) Any behavioral effect, it seems, should be easy to replicate in any lab at any time of the day with any sample of participants as long as the strong causal influence is present. This is the underlying assumption of experimental designs that are common in experimental psychological science, designed with the machine metaphor in mind. A typical experiment isolates one or two causal influences and manipulates them with the hopes of observing a strong effect on the behavioral outcome of interest.

But there's another possibility. If the psychological meaning of physical signals is relational, dependent on a complex web of other physical signals entangled in many weak, nonlinear interactions, then it is very likely that hidden causal factors are lurking in the context of the original experiment but differ in the attempted replication. This idea has been criticized as unscientific—so-called weasel words to avoid taking scientific responsibility for failed experiments (e.g., Yong, 2015). But from a view of relational meaning, grounded in complexity of causation, this possibility seems realistic and is likely very common. Psychological scientists rarely attempt to measure or manipulate the fuller web of influences. As a consequence, the impact of those influences—the variance they cause—mistakenly appears as error variance. This realization makes effect sizes of .30 look like an accomplishment rather than an embarrassment.

At minimum, problems with replication require us to reconsider the whole endeavor of multitrial, stimulus–response style experiments that are the bread and butter of experimental psychology (e.g., Hutchinson & Barrett, 2019), particularly because they catastrophically fail to account for the full causal web of influences (for a similar view, see Gergen, 1978). In principle, many scientists would not defend that the mind works in independent and discrete chunks in time. In practice, however, many experiments fail to recognize that a participant's response on any given trial is some combination of the signals that create the participant's internal model, the signals of a given stimulus, and the "background" signals of the participant's body and context. Ideally, psychological scientists should aim to model as many relevant signals as possible to maximize the robustness of scientific findings. Research has highlighted the utility of modeling brain and behavior in terms of continuous, temporally dependent processes (e.g., Huk et al., 2018; Spivey, 2007).

An apt example comes from the science of molecular genetics (described in Lewontin, 2000). A standard method for demonstrating that a gene is the source of a phenotypic characteristic, such as the development of neurotypical wings in a species of drosophila, is to identify mutations that disrupt normal development, such as producing curly wings rather than the usual straight ones. This mutation, however, produces curly wings only in a lab where contextual conditions like temperature and humidity are hidden in the "background context," carefully controlled, and not in the real world where temperature and humidity vary across a broad range of environments.

From this perspective, the science of emotion recognition is a cautionary tale about the risks of valuing reliability over validity. A finding that robustly replicates again and again (think universal emotion recognition via choice-from-array) is not necessarily evidence that the tested hypothesis is valid (think flies with curly wings). And yet, choice-from-array remains in broad use within psychology, in both scientific and clinical practice (e.g., see Betz et al., 2019, for the influence of choice-from-array in the "Reading the Mind in the Eyes" test), despite an entire century of evidence that this method nudges (or shoehorns) participants to provide certain responses, limiting what scientists can learn.

Conclusion

This article opened with a simple, everyday occurrence: looking at someone's face and seeing evidence of their psychological state. The experience is so automatic and effortless that it feels natural, as if we were detecting a biologically prepared, universal meaning. As perceivers, we are largely unaware of the multitude of factors (including the signals from our own body) that guide our actions and give rise to our experiences. This ignorance is reflected in the typological approaches that, despite more than a century of scrutiny and critique, still dominate large swaths of psychological science. When these other factors are considered, they are usually called "context" for the one or two causal influences that are the focus of experimental interest. In this paper, we grabbed hold of that single string—context—tugged it, and unraveled the dominant paradigm guiding much of psychological science today. Then we gathered the various threads—complex signal ensembles, relational meaning and population thinking—and began to weave a new approach, an alternative that, if taken seriously, could radically change our conceptions of what a mind is and how to best study it, in full awareness that our new story is not yet complete and must be compared and integrated where possible with other approaches that have been proposed as responses to the critiques of typologies.

Complexity, relational meaning, and population thinking have each been linked to paradigm shifts in other scientific fields. When Darwin (1859) proposed that a species (as a biological category) was a population of variable instances rather than a type, he prompted a paradigm shift in biology, a scientific revolution whose tremors are still felt today. Likewise for the early 20th century physicists who introduced quantum mechanics and observed that the world of solid objects, gravity, and so-called physical reality is actually a vast web of interacting quantities of energy, whose properties exist only in interaction with other quantities (Di Biagio & Rovelli, 2021; Rovelli, 2020; van Fraassen, 2010). And, who knows, a scientific revolution may still be in the offing for the mid-20th century scientists, engineers, and mathematicians who conceived of cybernetics, systems theory, and eventually complexity theory and complex adaptive systems (for a brief history, see Tilak et al., 2022; and references therein).

Maybe now it is psychology's turn. Many psychological scientists continue to formulate their hypotheses and understand their scientific practices in terms of a mechanistic model of causation that arose in a scientific revolution of the 16th century and remained unchallenged until the 19th and 20th centuries. This has serious implications. Science is more than a conceptual system for understanding how phenomena are caused. It is also a conceptual system for what phenomena are—an ontology of what exists. The science of emotion is a useful example in this regard. A recent survey indicates that a substantial number of psychological scientists who are experts in the science of emotion (80% of respondents) accept some form of a typological view (Ekman, 2016). Contextual factors, even powerful ones that transformed Serena Williams' face from terror to elation, are generally treated as mere moderators of prototypic signals with inherent emotional meanings—that is, as the exception rather than the rule.[16] As a result, facial movements are routinely called "facial expressions," as if they always display inherent psychological meaning (e.g., most recently, Cowen et al., 2021), which is a hypothesis to be tested, rather than a fact to be assumed; and certain configurations of facial movements are equated with "emotional expressions" (e.g., referring to scowling faces as "anger expressions"), rather than treating this correspondence as a hypothesis to be tested (e.g., for a recent example, see Schneider et al., 2022).

Breaking free of our typological roots may require a radical conceptual shift. This article has sketched one option: guiding our hypotheses and scientific practices by the idea that a mind emerges as a network of relations among signals, not as a collection of psychological modules with inherent, biologically prepared, independent psychological meanings. In this view, there is no single, universal human nature with a single set of universal psychological categories. The categories that a human brain is wired to construct, and the experiences of the world and the psychological meanings of actions that result, are not necessarily universal (as evidenced from numerous ethnographies in cultural and psychological anthropology). Instead, complexity, diversity, and the construction of relational meaning (i.e., the neural architecture and processes that create categories and allow for the cultural shaping of category learning) might be the hypothesized universals.

How can such a conceptual shift best be accomplished? Single investigators, their intrepid band of courageous mentees, and their trusting collaborators can craft and test novel hypotheses in the privacy of their own labs (assuming they can convince anyone to fund them). Siloed communities of other scientists can craft and test similar hypotheses as they have for more than a century. But the resulting work becomes knowledge only by the consent of a broad swath of scientists. Science is a human activity that operates in a social context. What counts as knowledge in any science depends on shared goals and agreements about which questions are admissible and which methods count as acceptable tools of inquiry. Ultimately, the value of the ideas and interpretations in this article depend on you, the reader. The questions you ask next, the studies you design from here on out, and the lessons you teach your students will help determine, in a complex ensemble of other scientists, whether psychology is ready to reconsider its typological preoccupations. The future of psychology as a science could depend on it.

[16] "… the contextual shaping of the recognition of emotion from facial-bodily expression may prove to be the exception rather than the rule" (Cowen & Keltner, 2020, p. 361).

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(*Appendix follows*)

Appendix

Figure A1
An Ecstatic Serena Williams After She Beat Her Sister, Venus, in the 2008 U.S. Open Tennis Finals (Photo Credit: Barton Silverman/The New York Times/Redux)

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